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Original Article

The Descriptive Epidemiology of Probable Sarcopenia in Community-Dwelling Tanzanians: A Cross-Sectional Observational Study

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Abstract

Objectives: This study presents the descriptive epidemiology of probable sarcopenia in a community setting in Eastern Africa. **Methods:** This is a cross-sectional observational study. Five random villages in Hai District, Kilimanjaro region, Tanzania, were selected. A total of 1207 community-dwelling adults aged 60 years and over were screened using a short frailty screening tool (B-FIT). A randomised frailty-weighted sample of 234 were included in analysis. Survey data and physical measurements including hand grip strength (HGS), Timed Up and Go (TUG) test, and bio-impedance analysis (BIA) were conducted. The prevalence of probable sarcopenia in the screened population was calculated using the revised European Working Group on Sarcopenia in Older People (EWGSOP2) guidelines. Logistic regression was used to explore associations between indicators of nutritional status and socioeconomic position, and probable sarcopenia. **Results:** The mean HGS in men was 28.5 kg (SD 10.4) and in women was 20.5 kg (SD 6.4). Estimated prevalence of probable sarcopenia in the community-dwelling population aged ≥60 years was 31.5% (95% CI 19.65-43.35) in men, and 9.79% (95% CI 5.95-13.63) in women. **Conclusions:** Probable sarcopenia was prevalent in a study of community-dwelling older Tanzanian adults. It is associated with markers of malnutrition and lower socioeconomic position in this context.

Keywords: Sarcopenia, Hand grip strength, Malnutrition, Socioeconomic position, Sub-Saharan Africa

Introduction

Sarcopenia, or "skeletal muscle failure" is associated with ageing[1], and will be an important condition to prevent, detect and manage in the continent with the fastest rate of demographic change, Africa[2]. Nevertheless, a research gap persists with none of the highly cited sarcopenia papers currently coming from Africa[3].

Epidemiological work on sarcopenia in Africa has been hindered by difficulties accessing diagnostic imaging techniques such as DEXA and MRI, making sarcopenia diagnoses more heterogenous[4]. Studies have sometimes

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been undertaken in contexts of clinical scarcity, for example in the single geriatrics-dedicated clinic in Cameroon, with reliance on low-resource quick screening tools such as the SARC-F screening questionnaire and the short physical performance battery[5,6]. Research from the African continent has also been hampered by a lack of normative data, with a systematic review of global variation in hand grip strength including only two African studies[7].

A systematic review published in 2023, identified 17 African studies of sarcopenia with a pooled sarcopenia prevalence of 25% overall, (95% CI 19-30)[4]. This relatively high prevalence was attributed to most of these studies being of hospital-based participants, therefore at increased risk of sarcopenia due to the acute illness episode, acute immobility and reduced caloric intake. The authors called for more community-based prevalence studies in Africa[4]. None of the included studies were of East African origin.

We theorised that, taking a life course approach, lower socioeconomic position would be associated with an increased risk of sarcopenia through early-life undernutrition leading to lower peak muscle mass, increasing the risk of sarcopenia in older age[8,9]. It has also been established that malnutrition increases the risk of incident sarcopenia[10]. Therefore, we hypothesised that in this context, where the main livelihood is subsistence farming[11], undertaking physical labour with inadequate nutritional compensation, may increase the risk of sarcopenia.

Aims

To investigate the prevalence of probable sarcopenia using the revised European Working Group on Sarcopenia in Older People (EWGSOP2) criteria[12], in a community-dwelling study population of older adults living in rural Tanzania.

To explore the associations of markers of nutritional status and socioeconomic position with probable sarcopenia.

Materials and Methods

This study is a sub-analysis of a larger prevalence study investigating frailty according to the comprehensive geriatric assessment[13], the frailty phenotype[14], and exploring frailty and social vulnerability indices[11]. The screening and evaluation methods have been described in detail in previously published work[13,15]. Initial screening was conducted of between 89% and 94.8% of the total population aged ≥60 years living in 5 randomly selected villages in a rural district of northern Tanzania, Kilimanjaro region. The screening comprised a tool termed the Brief Frailty Instrument for Tanzania (B-FIT)[16], which includes questions relating to function for the activities of daily living and an abbreviated version of a culturally appropriate cognitive screening tool termed the Identification and Intervention for Dementia in Elderly Africans (IDEA) tool[17]. The sample was randomly selected based on their B-FIT scores, with all those scoring poorly, half of those with intermediate scores, and ten percent of those scoring well, eligible for selection. In this manner, the final sample was weighted towards frailer participants, a method previously employed in epidemiological studies in lower income settings to maximise limited resources[18]. The survey and anthropometric measurements detailed below were carried out at sites close to the participants' homes, for example the village dispensary or local school, or if the participant preferred, or had difficulty mobilising, at their own home. These measures were used to investigate frailty prevalence and associations according to the frailty phenotype[14], and the frailty and social vulnerability index[11].

Diagnosis of probable sarcopenia

The cut-off points recommended by the EWGSOP2 were used to define probable sarcopenia, with low grip strength defined as <27 kg in men and <16 kg in women[12]. Hand Grip Strength (HGS) was measured with the elbow flexed at 90 degrees using a JAMAR Hydraulic Hand Dynamometer. Three readings were taken for each hand with the maximum of all six readings recorded as the maximum grip strength as suggested by the Southampton protocol[19]. Where participants were unable to complete the HGS measurement on one side (e.g. due to painful arthritis, or stroke) three readings from the opposite hand were used.

Estimates of muscle mass were calculated using Bioelectrical Impedance Analysis (BIA) (AKERN BIA 101 Florence, Italy). Participants lay supine for five minutes before electrodes were placed externally on the dorsal aspect of their right hand and foot. Signal electrodes were placed proximal to the phalanges and sensor electrodes were placed between the malleoli at the ankle and between the ulnar and radial styloid at the wrist. Appendicular Skeletal Muscle Mass (ASMM) was estimated using the Sergi equation[20]. To assess low muscle quantity, an Appendicular Skeletal Muscle Index (ASMI) from ASMM/height^2 was calculated. The EWGSOP2 cut-off points of <7.0kg/m^2 for men and <5.5kg/m^2 for women were applied[12].

Physical measures

Low physical performance was identified if the time to complete the Timed Up and Go (TUG) was ≥20 seconds[12]. The TUG was recorded as the time taken for participants to stand up from a seat, walk 3m, turn around, walk back and sit down using any footwear or walking aids they would usually use[21]. Participants who were unable to complete this test due to health or mobility reasons were also recorded as having "low physical performance". The research team attempted to limit variability in performance by ensuring a smooth walking surface was found, however this was not always possible due to conducting assessments in a variety of locations (for example the participant's home, the village dispensary, local schools) and in a variety of

weather conditions (for example where the road surfaces were slippery after rain, a surface was usually found indoors). The same wooden folding chair was used for all TUG assessments (chair height 45 cm).

Participants' heights were measured using the Marsden Leicester Height Measure and weight was measured using a digital weighing scale (the Microlife Diagnostic WS 80). Calf circumference (CC), hip circumference (HC) and waist circumference (WC) were measured with a flexible inelastic tape. The CC was measured around the widest part of the calf on the right-hand side unless there was an abnormality on this side. A cut-off point of CC <31 cm was taken as an increased likelihood of malnourishment. According to WHO recommendations, WC was measured at the midpoint between the lower margin of the lowest palpable rib and the top of the iliac crest, at the end of a normal expiration. Hip circumference was measured around the widest aspect of the buttocks, with the tape parallel to the floor[22]. These measurements were carried out with participants standing in a relaxed posture. The WHO cut-off points for increased risk of metabolic complications for waist-hip ratio were used (≥0.90 cm men, ≥0.85 cm women)[22].

The following question was taken from the International Physical Activity Questionnaire (IPAQ) to categorise moderate physical activity; "During the last 7 days, on how many days did you do moderate physical activities like gardening, cleaning, bicycling at a regular pace or other fitness activities?"[23]. Falls were recorded by self-report in response to the question "How many times have you fallen in the past year?". Blood pressure (BP) was measured three times in the participant's right arm with the participant sitting, using a digital blood pressure monitor (manufacturer A&D Medical UA-704). High BP was categorised as an elevated mean systolic BP ≥140 mmHg and/or diastolic BP ≥90 mmHg.

Nutritional and socioeconomic measures

The Mini Nutritional Assessment Short Form (MNA-SF) was conducted to assess nutritional status, categorising participants as malnourished, at risk of malnutrition or with a normal nutritional status[24]. The MNA-SF score was calculated using CC given that these data were more complete, and to allow comparison with BMI. The IDEA cognitive screening tool was used as a more objective measure of cognition in place of the MNA-SF neuropsychological questions, given that underdiagnosis of dementia and depression would otherwise have led to a significant under-estimation. Two variables relating to food insecurity were included, taken from the WHO SAGE individual questionnaire, for example "In the last 12 months, were you ever hungry, but didn't eat because you couldn't afford enough food?"[25] (Supplementary data Table 1).

Proxy markers of socioeconomic position included the question "What is the participant's highest level of schooling?", giving the option for "some primary school" as it was common for this generation of older adults to have started but not completed primary school. Further binary questions were used to explore financial security of older participants, for example "Does the participant receive a pension?", and "Is the participant completely financially/materially dependent on family?". Household wealth was estimated by the question "Does your home have electricity?".

Statistical Analysis

Data were downloaded from the secure ODK 0.2 aggregate online database, cleaned in Microsoft Excel 2016, and imported for analysis by StataMP 18 (64-bit) software. Simple descriptive statistics by sex in the whole frailty-weighted sample were tabulated. When calculating the prevalence of probable sarcopenia in the screened population, the weighted stratification was considered by using inverse proportions. To calculate confidence intervals (CI), bootstrapping (Stata command 'svyset') was used to control for clustering by village and to adjust for the stratified sampling. Individuals with missing data were excluded from prevalence calculations and logistic regression analyses were carried out on the sample with complete data. Binary logistic regression was used to calculate odds ratios for probable sarcopenia by variables of interest, adjusted by age category, sex and education status. The alpha value was set at 0.05. Stata command 'pvenn' was used to produce proportional Venn diagrams to visually represent the proportion of overlap and co-existence of probable sarcopenia, malnutrition and underweight. The binary logistic regression analysis and proportional Venn diagrams were conducted without taking account of sample weights.

Results

General characteristics of the study population

Descriptions of the study population, including prevalence estimates, are derived from analysis of the weighted sample. Table 1 describes the distribution of relevant sociodemographic, physical measures, and nutritional assessments, by sex for the frailty-weighted group (N=234). It shows a disparity in educational attainment by sex, where n=13 (13.1%) of men, compared with n=57 (42.2%) of women did not receive any school education. The majority of men were married at the time of the study n=68 (68.7%) whereas, the majority of women n=81 (60.0%) were widowed. Over half, n=70 (51.9%) of women and a third, n=33 (33.3%) of men were financially dependent on family members, in the absence of a pension (that a minority were in receipt of; n=10 (10.1%) men and n=7 (5.2%) women). Around one third of men in the sample were underweight, n=31 (31.1%) compared with n=13 (9.6%) of women. A BMI ≥ 25 kg/m^2 was more common

Table 1. Characteristics of the sample included in analysis, by sex.

	Men (N=99)	Women (N=135)
Sociodemographic variables Frequencies (%)		
Age group (years)		
60-69	38 (38.4)	49 (36.3)
70-79	28 (28.3)	40 (29.6)
80-89	22 (22.2)	21 (15.6)
90+	11 (11.1)	25 (18.5)
Highest educational attainment		
University or post-graduate	5 (5.1)	3 (2.2)
Completed secondary school	5 (5.1)	3 (2.2)
Completed primary school	40 (40.4)	24 (17.8)
Some primary school	36 (36.4)	48 (35.6)
No school education	13 (13.1)	57 (42.2)
Marital status		
Married	68 (68.7)	43 (31.9)
Widowed	19 (19.2)	81 (60.0)
Separated/divorced	10 (10.1)	9 (6.7)
Single	2 (2.0)	2 (1.5)
Occupation		
Farming or self-employed	30 (30.3)	39 (28.9)
Other paid work	12 (12.1)	0.0 (0.0)
Seeking work	2 (2.0)	2 (1.5)
Homemaker	4 (4.0)	13 (9.6)
Retired	20 (20.0)	26 (19.3)
Sick	31 (31.3)	55 (40.7)
Financially independent	66 (66.7)	65 (48.2)
Financially dependent on family	33 (33.3)	70 (51.9)
Health insurance	(n=98, missing 1 value) 22 (22.5)	38 (28.1)
No health insurance	76 (77.6)	97 (71.9)
Pension	10 (10.1)	7 (5.2)
No pension	89 (89.9)	128 (94.8)
Household electricity	38 (38.8)	67 (49.6)
No household electricity	60 (61.2) 1 refused to answer	68 (50.4)
Physical measures, Mean (SD)		
Maximum Hand Grip Strength (kg)	(n=88, missing 11) 28.51 (10.39)	(n=130, missing 5) 20.49 (6.39)
Appendicular skeletal muscle index (kg/m^2)	(n= 85, missing 14) 6.17 (1.03)	(n=113, missing 22) 5.68 (0.86)
Timed up and go (TUG) (seconds) Median (IQR)	(n=85, missing 14) 12.8 (9.9 – 17.5)	(n=115, missing 20) 16.17 (11.9 – 25.0)
Calf circumference (cm)	(n=97, missing 2) 31.40 (3.83)	(n=133, missing 2) 32.06 (4.23)

Table 1. *(Cont. from previous page).*

	Men (N=99)	Women (N=135)
Hip circumference (cm)	(n=91, missing 8) 91.48 (9.91)	(n=126, missing 9) 100.4 (11.40)
Waist circumference (cm)	(n=93, missing 6) 83.15 (13.74)	(n=128, missing 7) 88.63 (13.70)
Waist: hip ratio	(n=91, missing 8) 0.90 (0.08)	(n=126, missing 9) 0.88 (0.07)
Height (m)	(n=89, missing 10) 1.64 (0.08)	(n=121, missing 14) 1.54 (0.07)
Weight (kg)	(n=89, missing 10) 57.37 (13.94)	(n=122, missing 13) 59.52 (14.42)
BMI (kg/m²)	(n=88, missing 11) 21.25 (5.55)	(n=119, missing 16) 24.88 (5.13)
BMI categories (n=207)		
Underweight ≤18.49	31 (31.3)	13 (9.6)
Normal 18.50 to 24.99	38 (38.4)	46 (34.1)
Overweight ≥25.00-29.99	15 (15.2)	42 (31.1)
Obese ≥ 30.00	4 (4.0)	18 (13.3)
Missing	11	16
During the last 7 days, on how many days did you do moderate physical activities like gardening, cleaning, bicycling at a regular pace or other fitness activities?	None: 29 (29.3) 1 to 7 days: 70 (70.7)	54 (40.0) 81 (60.0)
Nutritional status (Frequencies, %)		
MNA-SF Category (maximum 14 points)		
Malnourished (0-7):	27 (27.3)	36 (26.7)
At risk (8-11):	38 (38.4)	56 (41.5)
Normal (12-14):	32 (32.3)	41 (30.4)
Missing:	2	2
Sarcopenia measures (Frequencies, %)		
Probable sarcopenia *Low muscle strength: (n=218)*		
Low HGS	36 (36.4)	28 (20.7)
HGS above the EWGSOP2 cut-off	52 (52.5)	102 (75.6)
Missing	11	5
Low muscle quantity: (n=198)		
Low ASMI	70 (70.7)	49 (36.3)
Above cut-off ASMI	15 (15.2)	64 (47.4)
Missing	14	22
Low physical performance (n=223)		
TUG ≥20 secs or unable	24 (24.2)	53 (39.3)
TUG <20 secs	71 (71.7)	75 (55.6)
Missing	4	7

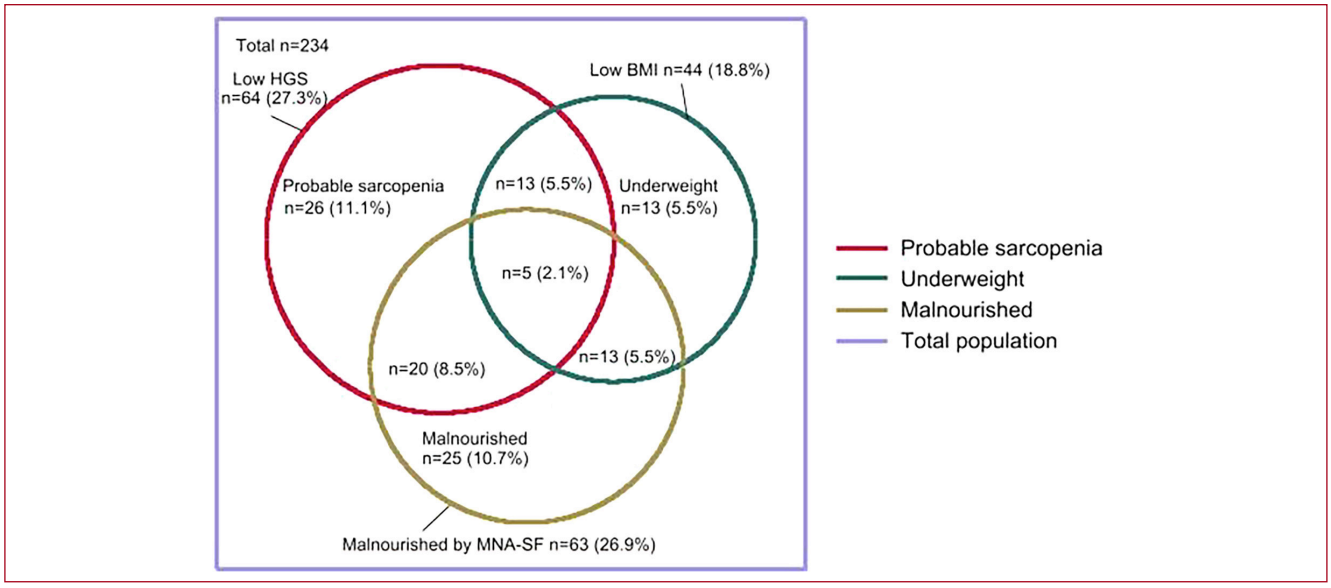

Figure 1. Proportional Venn diagram showing the relationship between probable sarcopenia, underweight and malnutrition.

Category	Prevalence in the total screened population (95% CI)	Prevalence in men (95% CI)	Prevalence in women (95% CI)
Probable sarcopenia (low HGS)	20.48 (12.15-28.80)	31.50 (19.65-43.35)	9.79 (5.95-13.63)
Low muscle quantity	56.62 (45.80-67.44)	80.45 (69.68-91.22)	30.91 (24.93-36.89)
Low physical performance	17.86 (13.21-22.50)	13.54 (7.49-19.58)	21.5 (14.18-28.81)
Malnutrition MNA-SF			
Malnutrition	19.05 (10.21-27.88)	20.99 (9.90-32.08)	15.67 (4.79-26.54)
At risk	40.97 (35.87-46.52)	39.13 (30.32-47.94)	43.19 (37.26-49.12)
Normal	39.97 (31.87-48.07)	39.87 (33.13-46.61)	40.36 (27.44-53.28)
BMI kg/m^2 categories			
Underweight	22.82 (14.38-31.25)	38.54 (25.33-51.75)	6.39 (2.46-10.32)
Normal	36.28 (29.38-43.18)	37.95 (27.79-48.10)	34.59 (19.05-50.13)
Overweight	27.68 (22.96-32.39)	17.65 (12.51-22.79)	37.94 (28.21-47.67)
Obese	13.21 (3.07-23.35)	5.86 (-2.56-14.29)	21.07 (7.13-35.01)

Table 2. Prevalence of probable sarcopenia and related measures in the screened population N=1,207).

among women, n=60 (44.4%) compared with n=19 (19.2%) of men. HGS was measured in 218 participants. Mean HGS among men was 28.51 kg (SD 10.39) and in women, 20.49 kg (SD 6.39). ASMI was calculated for 198 participants. The overall mean was 5.89 kg/m^2 (SD 0.96), while in men the mean was 6.17 kg/m^2 (SD 1.03) and in women 5.68 kg/m^2 (SD 0.86). Application of EWGSOP2 cut-off points to ASMI led to n=70 (70.7%) of men, and n=49 (36.3%) of women being categorised as having low muscle quantity.

A proportional Venn diagram (Figure 1) illustrates that whilst there was overlap between low BMI and malnutrition by the MNA-SF, n=26 (11.1%) of the sampled population had probable sarcopenia without being underweight or malnourished.

Table 3. Sociodemographic and physical measures by probable sarcopenia in the frailty-weighted sample.

Variable	No probable sarcopenia (n=154)	Probable sarcopenia (n=64)	Significance
Men	52 (33.8)	36 (56.3)	X^2 (1) = 9.49 P=0.002
Women	102 (66.2)	28 (43.8)	
Age group (years)			
60-69	78 (50.6)	8 (12.5)	X^2 (2) = 52.84 P<0.001
70-79	50 (32.5)	14 (21.9)	
80 and above	26 (16.9)	42 (65.6)	
Any school attendance	115 (74.7)	40 (62.5)	X^2 (1) = 3.26 P=0.07
No school attendance	39 (25.3)	24 (37.5)	
Married	80 (51.9)	23 (35.9)	X^2 (1) = 4.65 P=0.03
Widowed, divorced or single	74 (48.1)	41 (64.1)	
Health insurance	45 (29.4)	11 (17.2)	X^2 (1) = 3.52 P=0.06
No health insurance	108 (70.6)	53 (82.8)	
Working	53 (34.4)	8 (12.5)	X^2 (1) = 10.77 P=0.001
Retired or sick	101 (65.6)	56 (87.5)	
Financially independent	107 (69.5)	21 (32.8)	X^2 (1) =10.13 P<0.001
Financially dependent	47 (30.5)	43 (67.2)	
Household electricity	77 (50.3)	20 (31.3)	X^2 (1) = 6.64 P<0.01
No electricity	76 (49.7)	44 (68.8)	
TUG<20 secs	119 (78.8)	24 (41.4)	X^2 (1) = 27.17 P<0.001
TUG ≥ 20s or unable	32 (21.2)	34 (58.6)	
missing	3	6	
Normal nutritional status	63 (41.4)	9 (14.3)	X^2 (2) =18.95 P<0.001
At risk of malnutrition	62 (40.8)	29 (46.0)	
Malnutrition	27 (17.8)	25 (39.7)	
BMI kg/m^2:			
Underweight ≤18.49	25 (16.6)	18 (34.6)	X^2 (3) =13.87 P<0.003
Normal 18.5-24.99	60 (39.7)	22 (42.3)	
Overweight ≥25.00-29.99	45 (29.8)	12 (23.1)	
Obese ≥ 30.00	21 (13.9)	0	
missing	3	12	
Moderate physical activity			
1 to 7 days	127 (82.5)	23 (35.9)	X^2 (1) = 45.61 P<0.001
0 days	27 (17.5)	41 (64.1)	
IDEA cognitive screen:			
Good cognition 8-12	14 (9.1)	14 (21.9)	X^2 (2) = 11.28 P=0.04
Moderate cognition 5-7	26 (16.9)	17 (26.6)	
Poor cognition 0-4	114 (74.0)	33 (51.6)	

Table 4. Associations with probable sarcopenia in the frailty-weighted sample.

	Crude OR (95% CI)	Adjusted* OR (95% CI)
IPAQ (n=218)		
Moderate Physical activity	–	–
No moderate physical activity	8.39 (4.34-16.2) P<0.001	**9.73 (3.65-25.98) P<0.001****
Physical performance (n=209)		
TUG<20 secs	–	–
TUG ≥ 20s or unable	5.27 (2.74-10.11) P<0.001	**4.81 (1.83-12.65) P=0.001**
Cognitive screening (n=218)		
IDEA cognitive score 5-12	–	–
IDEA cognitive score 0-4	2.80 (1.25-6.28) P=0.01	1.92 (0.68-5.38) P=0.22
BMI kg/m^2 (n=203)		
Normal BMI (reference category) 18.5-24.99	1.00	1.00
Overweight ≥25.00-29.99	0.44 (0.73-3.26) P=0.44	1.01 (0.39-2.55) p=0.99
Underweight ≤18.49	1.96 (0.90-4.27) P=0.08	1.22 (0.49-3.06) p=0.67
Obese ≥ 30.00	–	0.00 –***
MNA-SF (n=215)		
Normal nutritional status	–	–
At risk of malnutrition	3.27 (1.43-7.48) P=0.005	2.44 (0.94-6.32) P=0.066
Malnutrition	6.48 (2.67-15.71) P<0.001	**3.95 (1.38-11.29) P=0.01**
(n=217)		
Health insurance	–	–
No health insurance	2.00 (0.96-4.19) P=0.06	1.83 (0.77-4.35) P=0.17
(n=218)		
Financially independent	–	–
Financially dependent	4.66 (2.49-8.70) P<0.001	**3.35 (1.45-8.65) P=0.005**
(n=218)		
Working	–	–
Retired or sick	3.67 (1.63-8.27) P=0.002	**2.73 (1.03-7.24) P=0.04**
(n=217)		
Household electricity	–	–
No household electricity	2.23 (1.20–4.13) P=0.01	**2.35 (1.12-4.94) P=0.02**

Adjusted for age category, sex, and education status. ** bold denotes significance with an alpha value of P <0.05. * Unable to calculate due to low N.*

Estimated prevalence of probable sarcopenia

The estimated prevalence of probable sarcopenia in the population screened by B-FIT of (N=1,207) was 31.5% (95% CI 19.65-43.35) in men, and 9.79% (95% CI 5.95-13.63) in women. The prevalence of underweight (BMI ≤18.49 kg/m^2) was 22.82 % (95% CI 14.38-31.25), (Table 2) and was more common in men 38.54% (95% CI 25.33-51.75) compared with women 6.39% (95% CI 2.46-10.32). Conversely, the prevalence of overweight and obesity was higher in women, 59.0% of women (95% CI 45.67-72.35) and 23.5% of men (95% CI 17.58-29.43) had a BMI ≥25.0 kg/m^2. The prevalence of low muscle quantity when EWGSOP2 cut-off points were applied produced prevalence estimates that were inconsistent with the muscle strength measures, particularly for men,

therefore estimates for confirmed and severe sarcopenia were not calculated.

Associations of nutritional status and socioeconomic position with probable sarcopenia: Regression analysis

Variables of relevance to our aim of investigating nutritional status and socioeconomic position were tabulated with probable sarcopenia (Table 3). Variables that demonstrated a statistically significant association with probable sarcopenia were included in further logistic regression analysis (Table 4). A further table included in the supplementary information file (Supplementary Table 2) shows that high blood pressure, falls in the past year, an increased waist-hip ratio, feeling hungry or eating less due to being unable to access food, and not having a pension did not differ between the no probable sarcopenia and probable sarcopenia groups.

Discussion

Prevalence of probable sarcopenia

The prevalence of probable sarcopenia in our study of community-dwelling older adults living in five villages in Tanzania was 31.50% (95% CI 19.65-43.35) in men aged ≥60 years and 9.79% (95% CI 5.95-13.63) in women. For comparison, an overall prevalence of sarcopenia of 25% was estimated in a pooled analysis of 17 African studies, but these are a very heterogenous group of studies, using several different measures for sarcopenia and conducted with a wide range of ages and in different settings[4]. The difference in prevalence between our study and other African prevalence studies, may in-part be explained by this being a community-based study, as opposed to a study with participants recruited through a hospital or clinic; only eight of the 17 studies in the meta-analysis were community-based[4]. A systematic review has analysed sarcopenia prevalence by different settings, finding a prevalence of 10% in community-dwelling individuals, whereas hospitalized individuals had a 23% prevalence[26]. Only two studies included in the systematic review of African studies used the EWGSOP2 guidelines and cut-off points; one was a community-based study that included adults aged 20-80 years[27], and the other a study of 65 patients with a fragility fracture of the hip[28], but prevalence estimates are not similar.

Associations of malnutrition and socioeconomic position with probable sarcopenia

This study found an almost four-fold increased odds of probable sarcopenia (indicated by low HGS) in those with malnutrition, when adjusting for age, sex and education. The prevalence of malnutrition was around the level expected, based on a recent systematic review, which found that community-dwelling adults aged ≥ 60 years in Africa, had a prevalence of 19.13%, based on an analysis of 23 studies[29]. These authors concluded that malnutrition is a public health problem among older adults in Africa. Our finding that older men had a higher prevalence of underweight and malnutrition, and older women a higher prevalence of overweight and obesity was reflected in a community-based study of three East African settings[30]. Older community-dwelling women in Tanzania, Kenya and Uganda had significantly higher BMI, triceps skinfold thickness and mid-upper-arm circumferences, and older men were significantly more underweight[30]. Cheserek et al. calculated mid-arm muscle area and found differences in muscle area were not significantly different between the sexes, which the authors suggest indicates older adults of both sexes are vulnerable to protein deficiency, despite different adiposity, in this context[30]. The reasons for this observation are likely to be complex and multifactorial, involving gendered norms in diet and physical activity behaviours, but more normative data and qualitative investigation are needed.

Associations of socioeconomic position with probable sarcopenia have been widely recorded. In our study population where 54.7% of participants reported no electricity in the home, this was a distinguishing marker of household wealth that was associated with a two-fold increased odds of probable sarcopenia. Only 10% of men and 5% of women were in receipt of a pension, thus, being financially dependent on family was often an indication of having reached a health state where manual subsistence farming was no longer possible to sustain. Being retired or too ill to work and being financially dependent were both associated with increased odds of probable sarcopenia. This could be interpreted as a reflection of current functional impairment (a relevant outcome of probable sarcopenia), or of contributory risk factors for probable sarcopenia, given that older people who did not, or were unable to, work may have been reliant on remittances from younger working family members, and thus their diet may have been poorer. This is an example of how the proxy measures of lower socioeconomic position used in this study require careful interpretation. Qualitative work in this setting revealed that older people viewed physical weakness with ageing as either a natural stage of life, or caused by resource scarcity, including inadequate nutrition[31]. Participants described missing meals and going hungry as well as having diets low in protein and reliant on "ugali" a filling carbohydrate[31].

Childhood and early life socio-economic position have been associated with reduced physical and cognitive capability in older age, including HGS[32,33]. In this study, household wealth was recorded based on having access to electricity, however the only proxy measure of early life socioeconomic position was education level. Access to education for this generation was restricted for women, and in this study was treated as a confounder in adjusted analyses. The lower average HGS across the life course

that was found in lower-income countries as compared with high-income countries highlights the need to take a life course approach to health inequalities in ageing[7].

Lack of normative data for older African populations

Whilst there are limited normative grip strength data available for our setting, some normative data have been published recently using combined data from South Africa, Tanzania, and Zimbabwe[34]. These data for healthy community-dwelling 61-70 year olds, found a median (25^{th}-75^{th} percentile) HGS value of 30 kg (21-38 kg) in men, and 18 kg (10-25kg) in women[34]. The highest HGS values were observed in Europe and North America, while the lowest values were recorded for Africa, South Asia and Southeast Asia[7]. These findings suggest that applying the EWGSOP2 cut-off points must be done with caution in older Africans. In this study, particularly in men, the EWGSOP2 cut-off point of ASMI <7.0 kg/m^2 was not deemed to be appropriate, especially as the 75th percentile was 6.75 kg/m^2.

The notable difference between men and women in their prevalence of underweight and overweight/obesity may have influenced the difference in prevalence of probable sarcopenia between the sexes. Kruger et al. in South Africa, aimed to develop an appropriate ASMI cut-point for black South African women acknowledging that European-derived cut-points may not be appropriately applied in black African populations[35]. They found the ASMI varied significantly between the overweight/obese women and those of normal BMI, and consequently the muscle mass cut-off points used were higher in the overweight/obese groups. In a systematic review and meta-analysis of sarcopenia prevalence, a wide variation in prevalence rates (between 9.9% and 40.4%) was found varying by the definitions used[36]. Differences in muscle mass thresholds used accounted for much of the between definition variation, and use of composite definitions (including muscle mass and muscle strength or function) tended to lead to lower prevalence rates, while BIA as opposed to DEXA tended to lead to higher sarcopenia prevalence estimates[36].

Strengths and limitations

Childhood and early life socioeconomic position or diet were not investigated in this cross-sectional study. Participant numbers were relatively low and under-powered to detect outcomes associated with probable sarcopenia. This study did not test participants for HIV, relying instead on self-report, however prevalence rates are low in Kilimanjaro region[37], and unlikely to have had a significant impact on our findings. This exploratory work, aiming to investigate associations with probable sarcopenia should be interpreted with caution, given that, with the exception of prevalence estimates, the stratified sampling of the survey design was not accounted for in analyses. This is a cross-sectional study therefore causality of relationships cannot be inferred.

To the authors' knowledge there are few community-based prevalence studies of probable sarcopenia in Eastern Africa. Attention should be paid to the generalisability of this study, given its relatively small size (including five villages), however the findings are likely to be relevant in other similar rural subsistence farming communities in Eastern Africa. Prevalence was not directly observed, limiting comparability with other community-based directly observed prevalence studies. It adds to the published literature, highlighting the important relationship between nutrition, socioeconomic position and probable sarcopenia, as well as raising the need for more normative data and studies investigating life course approaches to HGS and other functional measures important to ageing in different settings.

Ethics approval

Ethical approval was gained from three ethics review boards. In Tanzania, The Kilimanjaro Christian Research Ethics and Review Committee (CRERC) a local committee based at Kilimanjaro Christian Medical Centre (Ethical clearance certificate No. 998), The National Research Ethics committee (NatREC) for Tanzania, based at the National Institute for Medical Research (NIMR), Dar es Salaam (NIMR/HQ/R.8a/Vol.IX/2403). In the UK, Newcastle University Research Ethics Committee approved the study (application no: 01229/10058/2016).

Consent to participate

Assent was gained for participation from close relatives, in cases where the participant was unable to consent due to cognitive impairment. Signature or thumbprint were taken as forms of consent, and all forms were read aloud with participants so as not to exclude those unable to read or write due to educational attainment or sensory impairment.

Authors' contributions

All authors contributed to the study conception and design. Data collection and analysis were performed by Emma Grace Lewis, Samuel Bunn and Susan Hillman. The first draft of the manuscript was written by Emma Grace Lewis and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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Supplementary Table 1. Physical and nutritional measures by sex.

	Men N=99	Women N=135
Physical measures, Mean (SD)		
Skeletal muscle index (Kg/m^2)	(n=85, missing 14) 8.22 (1.22)	(n=113, missing 22) 6.10 (1.08)
Mid-upper arm circumference (cm)	(n=99) 25.55 (3.80)	(n=135) 28.15 (5.12)
Blood pressure	(n=97, 2 missing)	(n=133, 2 missing)
Systolic blood pressure	138 (29.9)	152 (30.8)
Diastolic blood pressure	76 (15.4)	82 (14.8)
High blood pressure (frequency, %)	43 (44.4)	83 (62.4)
Normal blood pressure	54 (55.6)	50 (37.6)
Falls: How many times have you fallen in the past year?	Twice or more: 15 (15.2)	19 (14.1)
	Once: 11 (11.1)	19 (14.1)
	No falls: 73 (73.7)	97 (71.9)
Nutritional questions, Frequency (%)		
In the last 12 months, how often did you ever eat less than you felt you should because there wasn't enough food?	Every month: 8 (8.1)	6 (4.4)
	Almost every month: 8 (8.1)	5 (3.7)
	Some months: 11 (11.1)	24 (17.8)
	One or two months: 6 (6.1)	13 (9.6)
	Never: 66 (66.7)	87 (64.4)
In the last 12 months, were you ever hungry, but didn't eat because you couldn't afford enough food?	Every month: 7 (7.1)	6 (4.4)
	Almost every month: 7 (7.1)	4 (3.0)
	Some months: 12 (12.2)	25 (18.5)
	One or two months: 5 (5.1)	12 (8.9)
	Never: 68 (68.7)	88 (65.2)
MNA-SF: Has food intake declined over the past 3 months due to loss of appetite, digestive problems, chewing or swallowing difficulties?		
Severe decrease:	6 (6.1)	9 (6.7)
Moderate decrease:	21 (21.2)	41 (30.4)
No decrease:	72 (72.7)	85 (63.0)
MNA-SF: Has the participant lost weight during the last 3 months?		
Weight loss > 3Kg:	5 (5.1)	9 (6.7)
Don't know:	22 (22.2)	48 (35.6)
Weight loss 1 to 3 Kg:	26 (26.3)	28 (20.7)
No weight loss:	46 (46.5)	50 (37.0)
MNA-SF: Has the participant suffered psychological stress or acute disease in the past 3 months?	Yes: 34 (34.3)	Yes: 47 (34.8)
	No: 65 (65.7)	No: 88 (65.2)
MNA-SF: Mobility		
Bed or chair bound:	7 (7.1)	11 (7.7)
Able to get out of bed/chair but does not go out:	26 (26.3)	56 (41.5)
Goes out:	66 (66.7)	68 (50.4)
MNA-SF: Calf circumference (n=230)		
<31cm:	50 (50.5)	51 (37.8)
31cm or greater:	47 (47.5)	82 (60.7)
Missing:	2	2

Supplementary Table 1. *(Cont. from previous page).*

	Men N=99	Women N=135
IDEA cognitive screening tool score from possible 12 (MNA-SF Neuropsychological problems)		
Poor 0–4:	8 (8.1)	29 (21.5)
Moderate 5–7:	17 (17.2)	29 (21.5)
Normal 8–12:	74 (74.7)	77 (57.0)
MNA-SF Category (maximum 14 points)		
Malnourished (0–7):	27 (27.3)	36 (26.7)
At risk (8–11):	38 (38.4)	56 (41.5)
Normal (12–14):	32 (32.3)	41 (30.4)
Missing:	2	2

	No probable sarcopenia (n=154)	Probable sarcopenia (n=64)	Significance
Pension	9 (5.8)	6 (9.4)	X^2 (1) = 0.88 P=0.34
No pension	145 (94.2)	58 (90.6)	
Did you ever eat less? No	101 (65.6)	40 (62.5)	X^2 (1) = 0.18 P=0.66
Did you ever eat less? Yes	53 (34.4)	24 (37.5)	
Were you ever hungry? No	102 (66.2)	42 (65.6)	X^2 (1) = 0.007 P=0.93
Were you ever hungry? Yes	52 (33.8)	22 (34.4)	
No increased waist-hip ratio	60 (39.7)	25 (41.7)	X^2 (1) = 0.06 P=0.79
Increased waist-hip ratio	91 (60.3)	35 (58.3)	
No falls	116 (75.3)	45 (70.3)	X^2 (1) = 0.58 P=0.44
Falls	38 (24.7)	19 (29.7)	
Normal BP	71 (46.4)	27 (42.2)	X^2 (1) = 0.32 P=0.56
Hypertension	82 (53.6)	37 (57.8)	

Supplementary Table 2. Variables not significantly associated with probable sarcopenia.

	Probable sarcopenia Crude OR (95% CI)	Confirmed sarcopenia Crude OR (95% CI)	Confirmed sarcopenia Adjusted* OR (95% CI)
Moderate Physical activity	–	–	–
No moderate physical activity (n=194)	8.39 (4.34–16.2) P<0.001	5.91 (2.86–12.2) P<0.001	**9.76 (2.98 –31.96) P<0.001****
Physical performance (n=188)			
TUG<20 secs	–	–	–
TUG ≥ 20s or unable	5.27 (2.74 –10.11) P<0.001	4.23 (2.02 –8.88) P<0.001	**4.83 (1.52 –15.34) P=0.008**
IDEA cognitive screening (n=194)			
IDEA score 5–12	–	–	–
IDEA score 0–4	2.80 (1.25–6.28) P=0.01	1.48 (0.53–4.12) P=0.45	0.77 (0.22–2.73) P=0.69
BMI (n=193)			
Normal BMI	–	–	–
Overweight	0.44 (0.73–3.26) P=0.44	0.45 (0.18–1.17) P=0.10	0.57 (0.19–1.62) p=0.29
Underweight	1.96 (0.90–4.27) P=0.08	2.13 (0.95–4.73) P=0.06	1.31 (0.52–3.33) p=0.56
Obese	–	–	0.00 *** –
MNA-SF (n=193)			
Normal nutritional status	–	–	–
At risk of malnutrition	3.27 (1.43–7.48) P=0.005	5.65 (2.03–15.68) P<0.001	**3.89 (1.25–12.12) P=0.019**
Malnutrition	6.48 (2.67–15.71) P<0.001	6.53 (2.14–19.95) P<0.001	**3.97 (1.09–14.31) P=0.035**
(n=193)			
Health insurance	–	–	–
No health insurance	2.00 (0.96–4.19) P=0.06	2.45 (1.02–5.89) P=0.04	2.09 (0.77–5.68) P=0.15
(n=194)			
Not financially dependent	–	–	–
Financially dependent	4.66 (2.49–8.70) P<0.001	2.97 (1.49–5.89) P=0.002	2.15 (0.83–5.61) P=0.12
(n=194)			
Not retired or sick	–	–	–
Retired or sick	3.67 (1.63–8.27) P=0.002	2.34 (1.01–5.39) P=0.05	1.77 (0.66–4.74) P=0.25
(n=194)			
Household electricity	–	–	–
No household electricity	2.23 (1.20 – 4.13) P=0.01	3.74 (1.73 – 8.12) P<0.001	**4.14 (1.67–10.23) P=0.002**

*Adjusted for age category, sex, and education status ** Bold denotes significance with an alpha value of P <0.05. ***Unable to calculate due to low N.

Supplementary Table 3. Crude OR for risk of confirmed and probable sarcopenia (low HGS).